# RAPID SYNTHESIS AND SIMULATION TOOLS  ELEMENT

of the
Intelligent Synthesis Environment Program

**Beth Plentovich, LaRC, Manager RSST**
**Dale Thomas, MSFC, Deputy Manager RSST**

ISE/Other Government Agency Workshop
Washington D.C.
June 22-23, 1999

# CONTENTS

- Goals and Objectives
- Requirements
- Work Breakdown Structure
- Element Overview
- Subelement Descriptions
- Technical Challenges/Issues
- Applications
- Coordination with Other Elements
- Resources
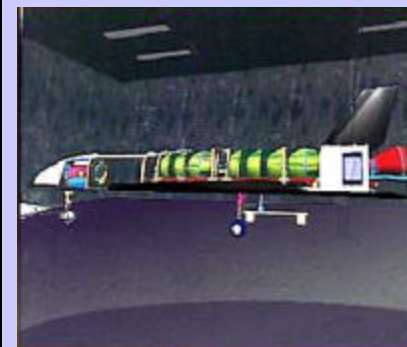- Summary

# Past, Present and Future

**Intelligent Synthesis Environment - OGA Workshop**

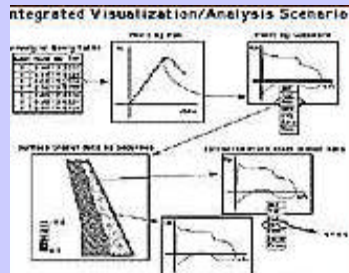**Digital Life & Full Virtual Product**

**Digital Process**

**Digital Mock-up**

**Where we want to be**

**Where we are now**

**Pre-CAD**

**2D Drawings**

**3D CAD**

**Where we've been**

# TECHNICAL CHALLENGES/ISSUES

- **Current modeling of complex designs takes months**

- **Engineers interact with computer software rather than the design**

- **Simulation based-design rarely used**

  - Excessive computer time required

  - Lack of validation for high-fidelity tools

- **Capability to analyze full life-cycle is immature**

# RSST GOAL

Develop and validate revolutionary engineering and science tools for synthesis and simulation of systems from concept through disposal to foster engineering creativity and productivity.

# RSST OBJECTIVES

- Reduce design and mission development time

- Reduce testing requirements

- Reduce costs related to redesign and rework

# LEVEL II REQUIREMENTS

- Advanced RSST tools must enable rapid simulation and analysis of the complete life cycle of a system, mission, or product

- Advanced RSST tools must meet the needs of all Strategic Enterprises across multiple mission types

- Advanced RSST tools must integrate into the ISE framework and be compatible with the CRMT, LCIV, CEE and RCCTE elements
  - Support the CEE application testbeds
  - Compliant with the environment defined by the LCIV
  - Integrable with the CRMT tools
  - Tool training methods compliant with the RCCTE architecture

# WORK BREAKDOWN STRUCTURE

```
                              ┌──────────────────┐
                              │  ISE Initiative  │
                              └──────────────────┘
```

| Rapid Synthesis and Simulation Tools (RSST) **1** | Cost and Risk Management Technology (CRMT) **2** | Life-Cycle Integration and Validation (LCIV) **3** | Collaborative Engineering Environment (CEE) **4** | Revolutionize Cultural Change, Training and Education (RCCTE) **5** |
|---|---|---|---|---|
| Synthesis Tools | Advanced Cost Tools | Systems Architecture | Collaborative Infrastructure Development | Education & Training |
| Simulation Tools | Advanced Risk Analysis Tools | Integration Methods | Applied Design & Analysis | Management Practices |
| Optimization & Design Space Exploration Methods | | R&D Applications | NASA Applications | Collaborative Team Environment |
| | | Engineering Process Assessment | Commercialization | |

# RSST OVERVIEW

**Description:**
Develop, assess, validate and demonstrate synthesis tools which seamlessly integrate diverse discipline tools and simulation tools which model and analyze complete component, sub-system and system life cycles from concept through disposal

**Current Status:**
- Great majority of tools are physics based and deterministic
- Tools are stand alone, at different levels of fidelity and do not integrate well
- Modeling of complex designs takes months
- Simulation-based design used rarely due to excessive computer time for high-fidelity tools
- Engineers interact with computer software rather than with the design

**Key Technology Needs:**
- Develop non-deterministic tools and get these into practice
- Develop non-traditional tools based on learning systems to dramatically reduce computer time
- Establish methods for seamless integration of diverse design tools

**Metrics**
- Reduce design cycle time to 1 - 1 1/2 years
- Reduce testing requirements by 75 %
- Reduce technology insertion time by order of magnitude
- Eliminate redesign and manufacturing rework

**Leverage Opportunities:**
- Aerospace, auto and engineering software industries
- Universities
- DARPA, DOE, DoD, NIST

# Rapid Synthesis and Simulation Tools

**Goal**

**Develop and validate revolutionary engineering and science tools for synthesis and simulation of systems from concept through disposal to foster engineering creativity and productivity.**

**Objectives**

| Reduce design & mission development time | Reduce mission failures and anomaly rates | Reduce life cycle costs |
|---|---|---|

**Challenges**

| Organizational cultures | Availability of methods which model time processes | Automated processes to select among discrete options |
|---|---|---|

**Approach**

| Develop rapid and intelligent tools to predict system or component performance | Develop tools to enable immersive simulation of all mission phases | Ensure integrability with benefit and cost studies tools to enable optimum system definition | Develop capability to evaluate multiple models at any stage in system life cycle |
|---|---|---|---|

**WBS**

| Synthesis Tools | Simulation Tools | Optimization & Design Space Exploration Methods |
|---|---|---|

ISE/RSST  10

# RSST ROADMAP

| | Formulation | | Implementation | | | | | '00 -'04 Totals |
|---|---|---|---|---|---|---|---|---|
| FY | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | |
| NASA $(M) | (0.0) | (0.0) | 4.6 | 9.9 | 11.2 | 13.2 | 13.2 | 52.1 |

Synthesis Tools

Traditional Analysis Tools & Methods

Synthesis TWG Planning

Develop Non-Traditional Design Techniques

Design/Analysis Technology

Design Synthesis Capability

Develop Modular Analysis Elements

Tools Integrated for Cost and Risk Assessment

Assess Current Practices

Generic Mission Architecture Development

Full Life Cycle Integrated Design Process Capability

Advanced Synthesis Practices

Simulation Tools

Simulation TWG Planning

Generic Simulation Language Development

Generic Simulation Capability

Model-Based Design/Analysis Tools

Simulation-Based Synthesis Feedback

Optimization & Design Space Exploration Methods

Single Discipline Optimization

Optimization & DES TWG Planning

Multidisciplinary System Optimization

Integration of Intelligent Agents in Design Optimization Strategies

Advanced Optimization for Mission Saftey and Design

Commercial Consortium

Identify Potential Partners

Cooperative Agreements

Cost-Sharing Partnerships

L2 Milestone

# SYNTHESIS TOOLS DESCRIPTION

- **Traditional tools**

    - discipline

    - tightly coupled disciplines

    - integration of analysis and design

- **Non-traditional tools (learning tools)**

    - genetic algorithms

    - fuzzy logic

    - artificial neural nets

- **Smart tools and models**

    - intelligence

    - self-healing

- **Modular analysis elements**

- **Design synthesis capability**

# Rapid Simulation With Computationally Intelligent Tools
# Neural Network Example

- **Rapid configuring of neural net to support plug & play interactive design**
- **Utilize available net software**
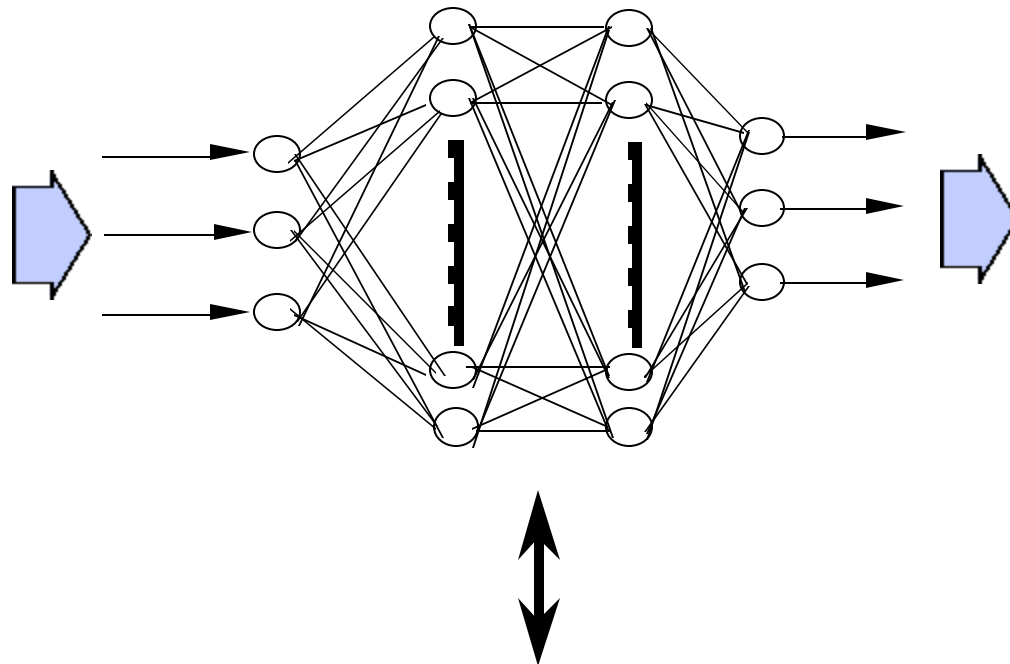
**Ultra-rapid simulations**

<u>**Rapid Training**</u>
- **rapid assembly**
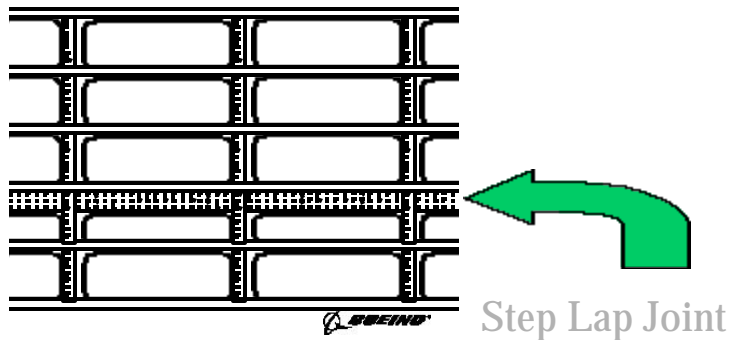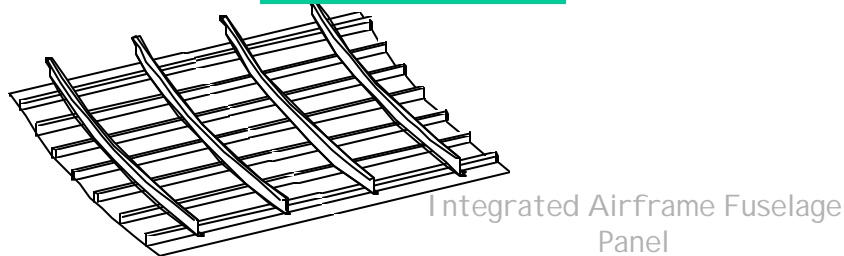- **rapid analysis using distributed/parallel computing**

# Non-Deterministic Design Saves Weight While Enhancing Safety

## Focus Problem
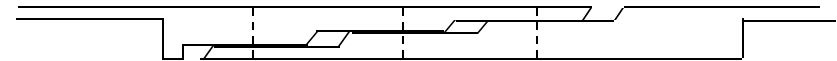
Integrated Airframe Fuselage Panel

Step Lap Joint

### FAILURE ANALYSIS:

- ➤ **Probabilistic Fatigue Life Analysis of Step Lap Joint**
- ➤ **Cyclic loading due to pressure difference between ground and cruise altitude**
- ➤ **Random Variables: Fatigue and Elastic Properties, Max. Applied Load**

## Conventional Design

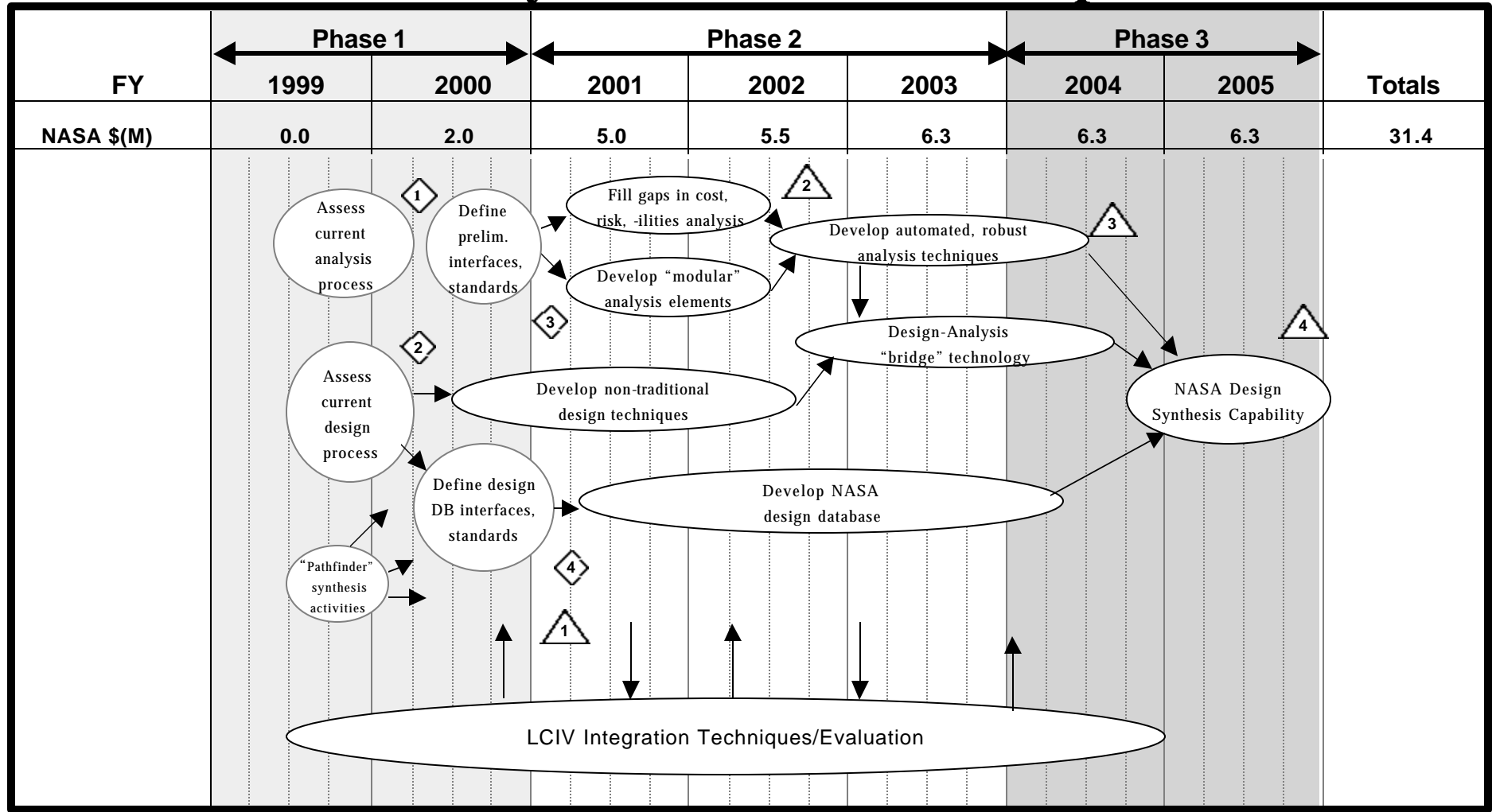## Reliability-Based Optimized Design



Weight vs Reliability chart:
- 0.99 → 0.80
- 0.999 → 0.81
- Conventional → 1.00
- 0.9999 → 0.82
- 0.99999 → 0.84
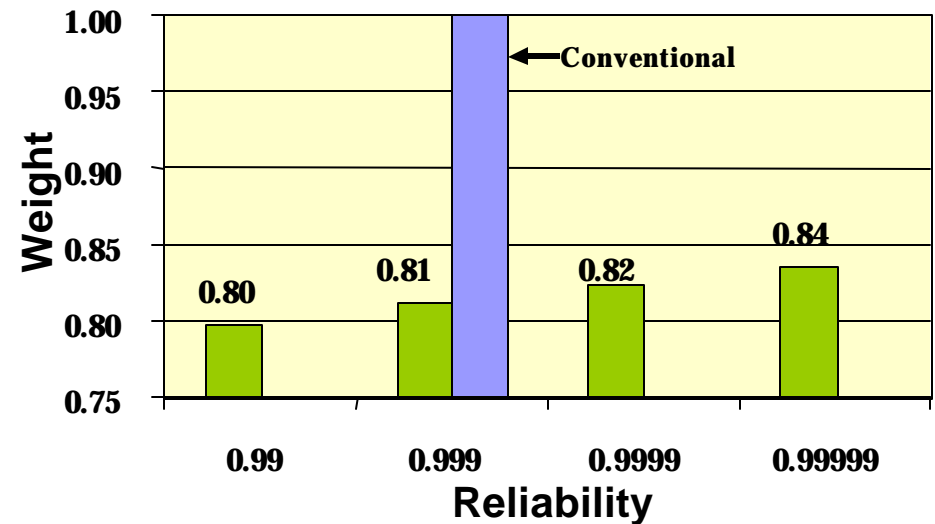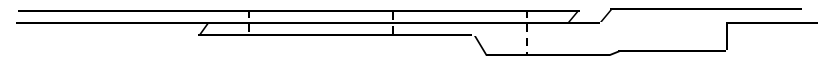
## Results

- ➤ **19% weight reduction --- same reliability**
- ➤ **Safer designs are almost free**

# RSST - Synthesis Tools Roadmap

| | Phase 1 | | Phase 2 | | | Phase 3 | | |
|---|---|---|---|---|---|---|---|---|
| **FY** | **1999** | **2000** | **2001** | **2002** | **2003** | **2004** | **2005** | **Totals** |
| **NASA $(M)** | 0.0 | 2.0 | 5.0 | 5.5 | 6.3 | 6.3 | 6.3 | 31.4 |



△ m L2 Milestone   ◇ n L3 Milestone   ○ Decision Point

ISE/RSST  15

# SIMULATION TOOLS DESCRIPTION

- **Process simulation methods and tools**
    - virtual missions
    - virtual manufacturing processes
    - virtual product assembly
    - virtual prototype
    - virtual testbed
- **Application-generic programmable simulation tools**
- **Mission-generic model operation language for simulation of wide range of applications**
- **Fidelity and duration sensitive mission system simulation methods**

# RSST - SIMULATION TOOLS

**Goal**

Create accurate, rapid, cost-effective virtual presence of mission system, life-cycle process, and mission operation environment

**Objectives**

| Comprehensive concept verification | Rapid design validation | Virtual life-cycle implementation |

**Challenges**

| Multi-discipline integration & multi-enterprise coordination | Model-fidelity & simulation accuracy validation | Precise and perceptive simulation process controlling and monitoring |

**Approach**

| Multi-discipline mission model architecture | Evolutionary mission life-cycle simulation | Fidelity & duration sensitive model/simulation | Integrated/collaborative design-oriented simulation tools |

**WBS**

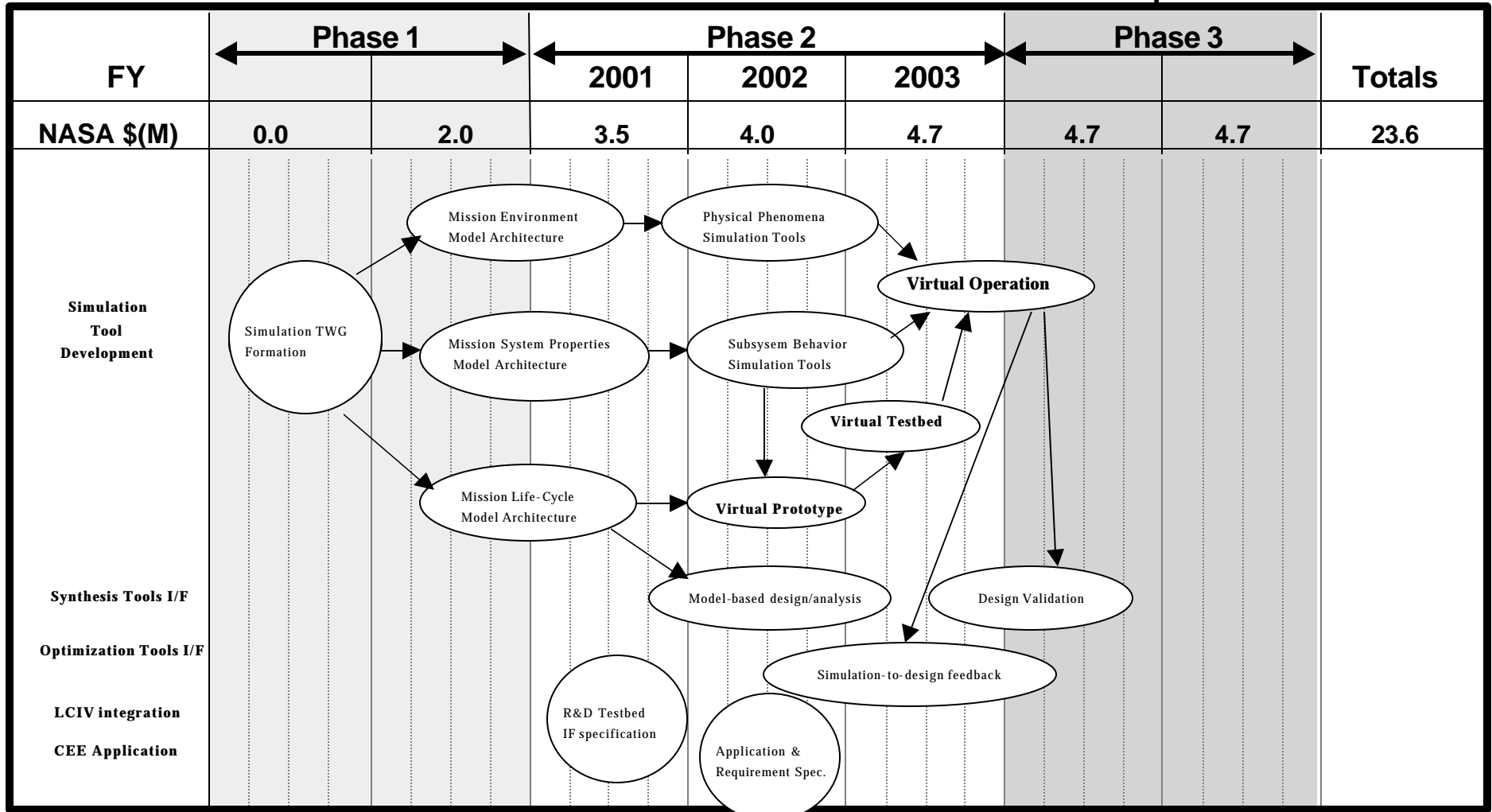| Mission environment simulation | Mission system property simulation | Mission life-cycle simulation |

ISE/RSST  17

# RSST - Simulation Tools Roadmap

| FY | Phase 1 | | Phase 2 | | | Phase 3 | | Totals |
|---|---|---|---|---|---|---|---|---|
| | | | 2001 | 2002 | 2003 | | | |
| NASA $(M) | 0.0 | 2.0 | 3.5 | 4.0 | 4.7 | 4.7 | 4.7 | 23.6 |

**Simulation Tool Development**

Simulation TWG Formation

Mission Environment Model Architecture

Physical Phenomena Simulation Tools

**Virtual Operation**

Mission System Properties Model Architecture

Subsysem Behavior Simulation Tools

**Virtual Testbed**

Mission Life-Cycle Model Architecture

**Virtual Prototype**

**Synthesis Tools I/F**

Model-based design/analysis

Design Validation

**Optimization Tools I/F**

Simulation-to-design feedback

**LCIV integration**

R&D Testbed IF specification

**CEE Application**

Application & Requirement Spec.

△ L2 Milestone   ⬡ L3 Milestone   ◯ Decision Point

ISE/RSST  18

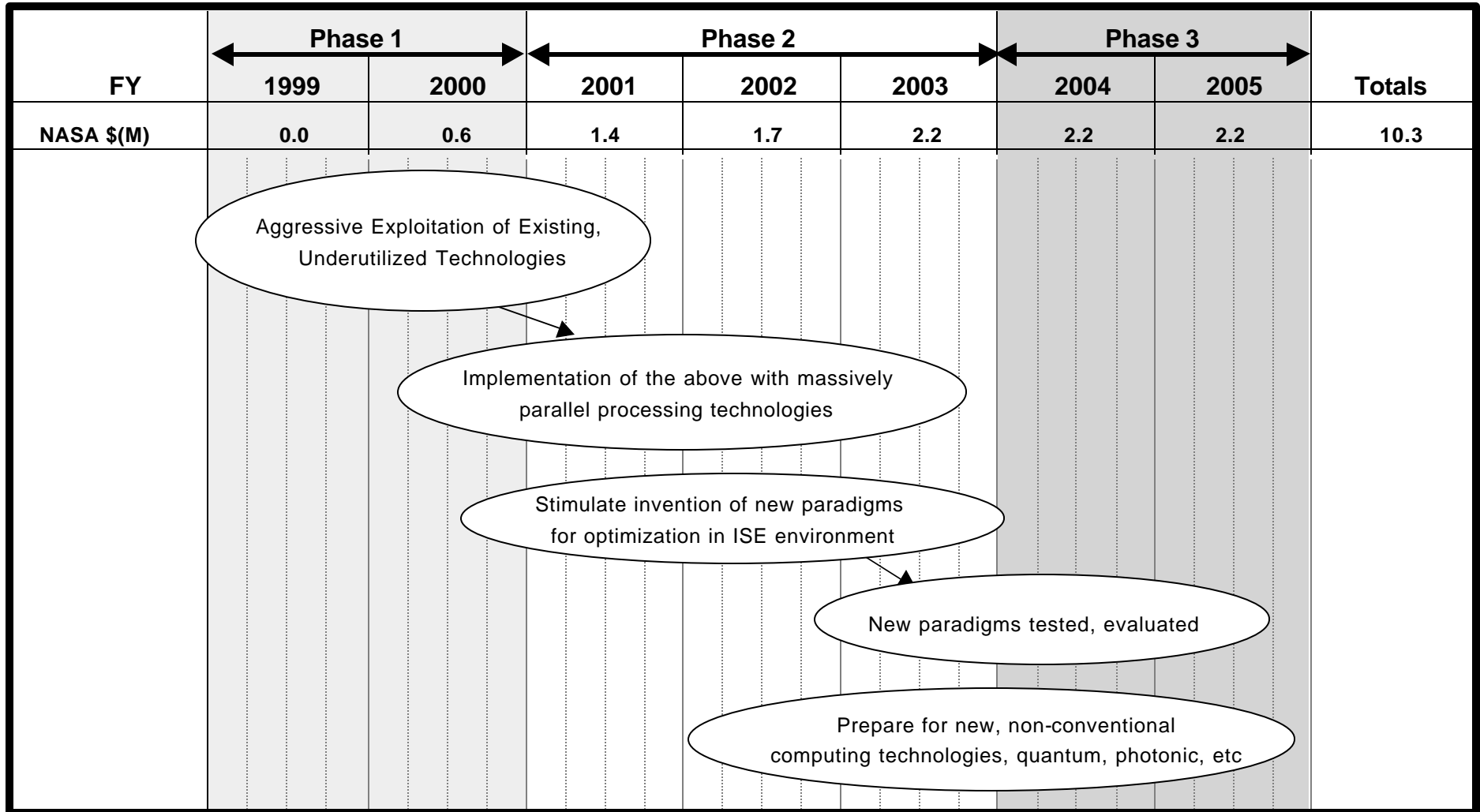# OPTIMIZATION & TRADE STUDY METHODS DESCRIPTION

- **Existing, underutilized techniques**

    - sensitivity methods

    - pattern, gradient-free methods

    - decomposition methods

    - genetic, evolution, and neural net methods

- **New paradigms that exploit synergy of human mind and computer**

- **Exploit new innovative computing technologies**

Intelligent
Synthesis
Environment

# OPTIMIZATION & TRADE STUDY METHODS DESCRIPTION

|  | Phase 1 | | Phase 2 | | | Phase 3 | | |
|---|---|---|---|---|---|---|---|---|
| FY | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | Totals |
| NASA $(M) | 0.0 | 0.6 | 1.4 | 1.7 | 2.2 | 2.2 | 2.2 | 10.3 |

Aggressive Exploitation of Existing, Underutilized Technologies

Implementation of the above with massively parallel processing technologies

Stimulate invention of new paradigms for optimization in ISE environment

New paradigms tested, evaluated

Prepare for new, non-conventional computing technologies, quantum, photonic, etc

△ **m** L2 Milestone ◇ **n** L3 Milestone ○ Decision Point

ISE/RSST  20

# ELEMENT INTEGRATION PLAN

- CRMT
  - Coordinate to ensure tools can be used together productively
  - Ensure interface requirements in RSST & CRMT support each other

- LCIV
  - Tools will be compliant with the environment defined by LCIV
  - Implement LCIV standards and system architecture as the foundation for tool development
  - Provide advanced tools for integration by LCIV
  - Compatibility and acceptability of advanced tools verified by LCIV
  - Refine tools based on lessons learned in LCIV simulations
  - Provide requirements to LCIV for future ISE system architectures
  - Use of LCIV R&D labs for tool development & testing

# ELEMENT INTEGRATION PLAN (Cont'd)

- CEE

  - Support CEE application testbeds

  - CEE application requirements used in defining near-term capability needed

  - Advanced application tools tailored and tested by CEE

  - Update tools based on lessons learned in CEE applications

- RCCTE

  - Support need for cultural change

  - Support development of training material

  - Provide training requirements for tools

  - User interface requirements provided by RCCTE

# RESOURCES (BUDGET AND FTE)

| FY | 2000 | 2001 | 2002 | 2003 | 2004 |
|----|------|------|------|------|------|
| $M | 4.6 | 9.9 | 11.2 | 13.2 | 13.2 |

# Summary

- TWG's are establishing high-level technology requirements, then bore down to refine these requirements

- RSST Work Breakdown Structure in place with project planning leads assigned

- Developing a collaborative engineering partnership for RSST technology development